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Mechanical properties of injection molded products fabricated by Direct Fiber Feeding Injection Molding

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Abstract

Direct-fiber-feeding injection molding (DFFIM), with the improvement of the screw and cylinder and a fiber-direct-feeding method, is a new way to make short fiber reinforced composite material from one step by throwing fiber into a formation machine directly, in which the traditional compounding process can be unnecessary. At current study, the well-distributed fiber and improved interface/interphase between fiber and plastic are aimed to achieve a cost-performance-ratio, through those achievements such as design of screw or the other combination conditions during DFFIM process. As for carbon fiber, besides filaments, there are many types including tow, staple yarn, chopped strands, compound, and so on. Those different reinforcement forms were adopted and used to make CFRP by DFFIM to investigate their mechanical properties. In particularly in this paper, PA6 resin and CF/PA66 commingle yarn was used as matrix and reinforcements for comparison. It is observed that the SEM dispersion state and interface /interphase increased.

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Keywords: carbon nanotube; dispersion; electrospinning; surfactant

1. Introduction

From expectations of strong and improve fuel efficiency by lightweight characteristics of carbon fiber composite material, a full-fledged application to automotive field has been studied as a breakthrough to the fuel economy

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regulations [1-4]. The development of low-cost carbon fiber composite material, as well as causing a technological innovation with the introduction of high-efficiency production process, full-scale adoption of carbon fiber composite material has become a realistic to market to the production car.

Improvement to the screw cylinder for the VENT type molding machine that fibers directly fed on an injection molding called DFFIM (Direct Fiber Feeding Injection Molding) enabled conventional composite molding process that compound pelletizing is not required [5]. It is possible to mold a short fiber reinforced composite material (short fiber reinforced composite) in one step. The improvement of molding efficiency has been studied.

However, DFFIM compared to short fiber-containing pellets that are created in the compounding process, flow dispersion of fibers has become a problem. Fibers of the short fiber-containing pellets were prepared by extrusion is made in a state of being dispersed after melting pellets, fiber distribution after injection molding depends flow flows inside the molding. However, DFFIM method, since directly on the carbon fiber bundle, flowing flow, screw rotation speed, screw rotation time, melt viscosity of the resin, depending on several factors such as ease of separation of carbon fiber dispersed state.

In this study, different material to put into fiber direct input injection molding, what kind of impact on the fiber distribution, the fracture surface was observed to consider SEM.

2. Experimental

2.1. Equipment

In molding equipment 30t clamping force of TOYO MACHINERY & METAL CO., LTD made injection molding machine (PSS TT-30F6) in Nihon Yuki Co., Ltd. made a vent type heat plasticizing unit and resin metering equipment (Hungry feeder HF-I type) was used. Carbon fibers are introduced directly from the vent opening, which is a matrix resin and kneaded in a screw cylinder injection molded during weighing. An overview diagram of the molding machine I is shown in Fig.1.

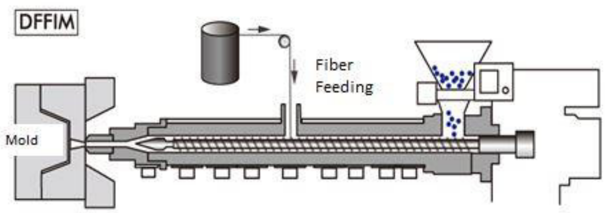


Fig. 1. Schematic of Direct Fiber Injection Molding.

2.2. Materials

For matrix resin, PA6 (TORAY) is used. Two types of reinforced fiber are chosen for comparison. Firstly, carbon Fiber (MITSUBISHI RAYON). Secondly, commingle yarn; Carbon fiber and PA66

2.3. Characterization

The dumbbell specimen of JIS K7113-1 standard is molded. To observe changes in physical properties due to the fiber content, the resin supply amount was adjusted with Hungry feeder in 20rpm, 40rpm, and 60 rpm. Slower the matrix resin feeding rate increases the fiber content. Other molding conditions were set the same for all specimens.

Tensile test was conductedon an Instron type 4466 with measuring speed 1mm/min and observed the fractured surface of the test piece in SEM.

3. Results and discussion

3.1. Tensile test

Tables 1 shows the result of tensile strength of carbon fiber and commingle yarn with 3 types of matrix resin feeding rate controlled by Hungry feeder HF-1. The result of the above table compared in graphically is shown in Fig. 2.

Table 1. Tensile strength with matrix resin

Tensile Strength (MPa)	Matrix Resin Feeding Rate								
	20 rpm			40 rpm			60 rpm		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Carbon Fiber	103	112	107	69	75	71	51	57	54
Commingle yarn	125	143	137	95	109	101	82	94	87

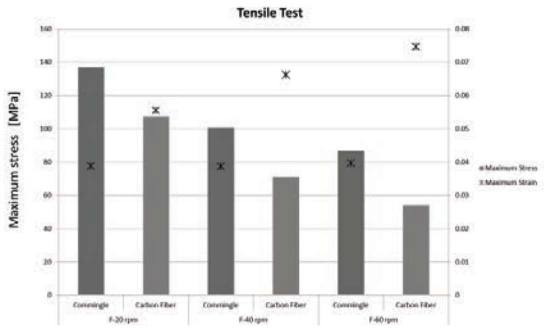


Fig. 2. Tensile Test for Different Type of Reinforced Fiber.

It is confirmed that more than 30 MPa of tensile strength is improved with the use of commingle yarn. Furthermore, as matrix resin feeding rate increase which means more fiber content, the tensile strength becomes greater.

The tensile strength of test specimens which are molded by commingled yarn are measured to be greater. It has been found in this experiment that the mechanical properties are changed with different fiber reinforced material.

In the case of commingle yarn, the strain at the maximum tensile stress is beyond the influence of fiber content. On the contrary, the strain at the maximum stress became greater as the content of fiber decreases.

Those that affect the difference in the tensile strength of the material are surface treatment agent for carbon fiber, the carbon fiber content, fiber length, fiber distribution, interface adhesion, and the reinforcing effect of PA66.

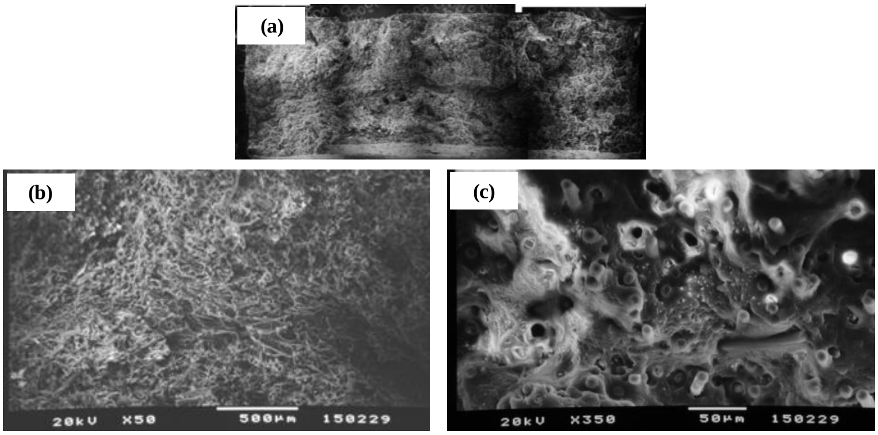
3.2. Scanning electron microscope

The fracture surface of the test pieces molded at a different reinforced fiber is observed by SEM, and it is shown in the following figure. The point of observation is whether fiber is well distributed, which means that there is no aggregation of fiber, and interface between fiber and resin is cohesive.

Fig. 3, it can be seen that the fibers are uniformly dispersed for carbon fiber/PA6 with matrix resin feeding rate 20rpm that means no aggregation of fiber is observed. For interface cohesion, the SEM photograph of a higher magnification is shown in below.

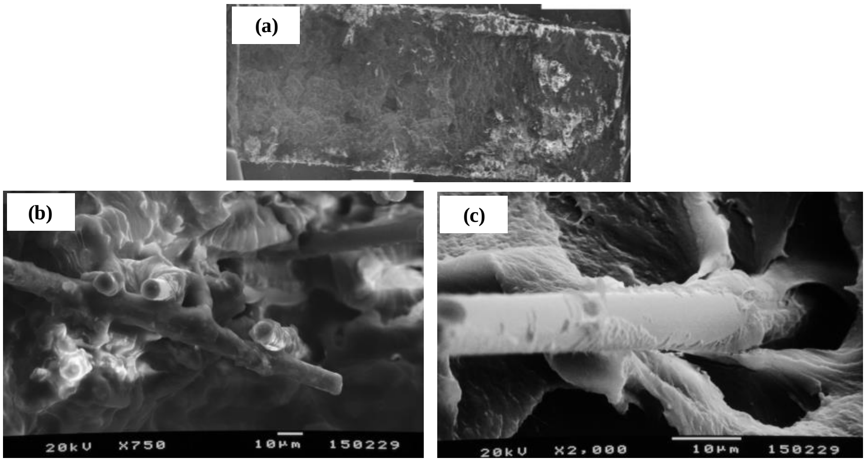
The interface of fiber and the resin is not sufficiently adhered, and is in a state where fibers are missing spots from the resin.

Even when it is molded in commingle, fibers are uniformly dispersed. Also, it was confirmed that the resin is state of adhesive to the fiber. However, the adhesion state of the interface compared to the resin feed rate 20rpm of Fig. 4 (b), resin is not adhered to the fibers and the gap between the resin and the fibers were confirmed



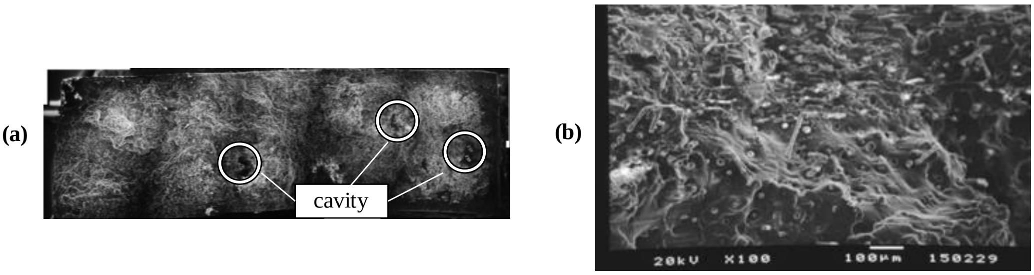
1-A.Carbon Fiber/PA6 with matrix resin feeding rate 20rpm

Fig. 3. (a) Carbon Fiber/PA6 (b) Carbon Fiber/PA6 (×50) (c) Carbon Fiber/PA6 (×350).



1-B.Commingle/PA6 with matrix resin feeding rate 20rpm

Fig. 4. (a) Commingle/PA6 (resin feed rate 20rpm) (b) Commingle /PA6 (×750) (c) Commingle /PA6 (×2,000).



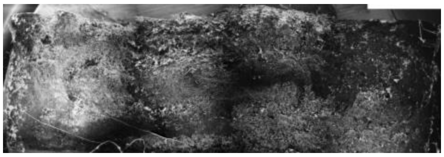
2-A.Carbon Fiber/PA6 with matrix resin feeding rate 40rpm

Fig. 5. (a) Carbon Fiber/PA6 (resin feed rate 40rpm); (b) at magnification ×100.

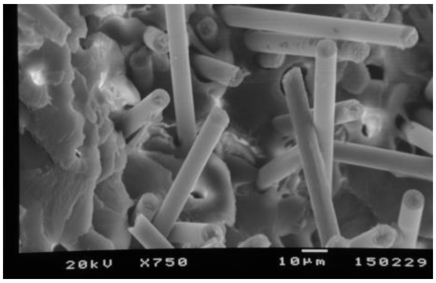
Although fiber was confirmed to have been uniformly dispersed, the cavity portions are observed. Same as Fig. 4 of different matrix resin feeding rate, the interface of fiber and the resin is not sufficiently adhered. Compared with the dispersibility of the carbon fibers showed in Fig. 5(a), aggregation of fibers is not observed.

At 60 rpm, fibers appear to be uniformly dispersed, but aggregation of the resin is confirmed due to the increase of the resin supply amount as shown in Fig. 7.

(a)



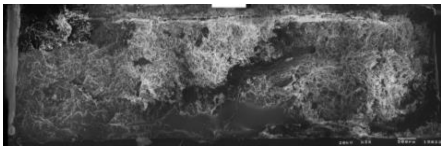
(b)



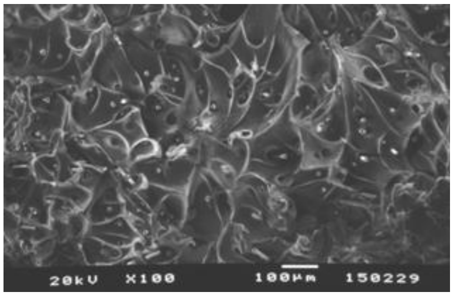
2-B.Commingle/PA6 with matrix resin feeding rate 40rpm

Fig. 6. (a) Commingle Fiber/PA6 (resin feed rate 40rpm); (b) at magnification ×750.

(a)



(b)



3-A.Carbon Fiber/PA6 with matrix resin feeding rate 60rpm

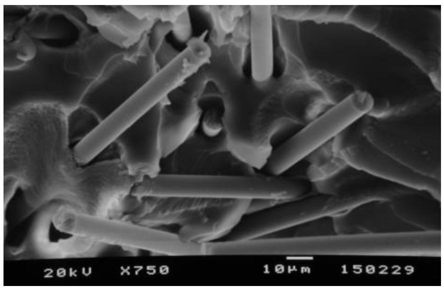
Fig. 7. (a) Carbon Fiber/PA6 (resin feed rate 60rpm); (b) at magnification ×100.

It is observed that the fiber and resin interface is further increasing gap compared to different resin feeding rate such as Fig. 3 (c) and Fig. 5 (b).

Supply amount of the resin is in the increased or decreased, it was confirmed that influence the interfacial bond. If it is set the same molding conditions, and that the resin supply amount is increased, the filling time of the screw is shortened. In other words, the fact is speculated that the resin and the fibers of the kneading time is shortened that is an influence of the interfacial adhesion.

(a)

(b)



3-B.Commingle/PA6 with matrix resin feeding rate 60rpm

Fig. 8. (a) Commingle Fiber/PA6 (resin feed rate 60rpm); (b) at magnification ×750.

It is seen that the fibers are well distributed and no cavity is observed. It looks the same fracture surface with Commingle/PA6 with matrix resin feed rate 40rpm. By using commingle yarn, the dispersion state may not be influenced. Although some portion of the resin is adhesive to the fiber, interfacial bond is insufficient compared with Fig.5 of matrix feeding rate 20 rpm.

4. Conclusions

For this research, different reinforcement forms were adopted and used to make CFRP by DFFIM to investigate their mechanical properties. To observe changes in physical properties due to the fiber content, the resin supply amount was adjusted with Hungry feeder in 20rpm, 40rpm, and 60 rpm.

It was confirmed that the tensile strength is measured to be greater for commingle yarn molded by DFFIM. In the case of commingle yarn, the strain at the maximum tensile stress is beyond the influence of fiber content. On the contrary, the strain at the maximum stress became greater as the content of fiber decreases. The fact is that the fiber is uniformly dispersed, and also, the interface between fiber and resin is more adhesive. For carbon fibers, the surface treatment agent is added, so it is considered as one effect on interfacial adhesion.

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